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The paradox of a complex vibration-insulated system and cost efficiency

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Abstract

The compression of the molding process in a metal foundry usually involves vibration-related problems in the civil area. Currently there are two common compression methods: hydraulic and impact compression. The former method is related with a highly expensive, conventional machine, which causes comparatively lower vibration levels. The latter is related with a much cheaper machine, which however causes high vibration levels, but on the other hand, has the capacity to produce more complex, smoother and more precise products.

The choice to be made is to choose between higher and lower costs, higher and lower quality of the products, and between higher and lower vibration levels in the civil area. The key question is whether a good quality product is possible at lower costs and with lower vibration levels. Therefore it is necessary to investigate the possibilities to reduce the vibration levels using a vibration-insulated system, starting from an impact compression method.

By means of measurements on similar machines, transfer measurements on the soil and finite element method (FEM) calculations, a complex insulated system can be designed and realized. In practice is shown that a complex insulated system can be very (cost) effective.

1. Introduction

During a development plan of an aluminium foundry, the company requests to purchase a new molding machine. Currently there are two common compression methods: hydraulic and impact compression. The former method is related with a highly expensive, conventional machine, which causes comparatively lower vibration levels. The latter is related with a much cheaper machine, approximately € 500.000,- cheaper, which however causes high vibration levels, but on the other hand, has the capacity to produce more complex, smoother and more precisely products. Since a lot of dwelling-houses are situated in the vicinity of the company (nearest at approximately 40 meters), vibration levels leave their mark on the decision of the foundry company.

In order to get more insight in the possibility to reduce the vibration levels of the impact molding machine in the vicinity of the foundry company, a case-study is performed. The intention of the study is to design a vibration-insulated system in order to reduce the vibration levels caused by the molding machine in the dwellings to maximal 0,1 mm/s (approximately the level of perception) as well as to calculate the additional cost related to the vibration-insulated system. By means of this study the foundry company can make a cost-benefit analysis.

2. Quantifying the (design) parameters

By means of measurements on similar machines, transfer measurements on the soil on the spot and finite element method (FEM) calculations (see also chapter 4), the force-spectrum of the molding-process is determined. The soil can be described accurate with two distinguished soil-layers. The material properties of the soil-layers are based on (transfer) measurements and empirical data [4].

3. Final design of the vibration-insulated system

In order to define the final values of some of the parameters and the dimensions, a parameter study has been made. During the parameter study mainly the influence of the dimensions of the concrete foundation block (mass), the sheet pile wall (length) and the properties of the resilient mounting pads are determined.

In figure 1 the final design of the vibration-insulated system is given. The mass of the concrete foundation block is approximately 80.000 kg (4x8 meter). This foundation is mounted on a waterproof foundation block, using resilient mounting pads. Furthermore a sheet pile wall (around the total foundation) is used in order to create an additional impedance. The depth of this sheet pile wall is approximately 8 meter.

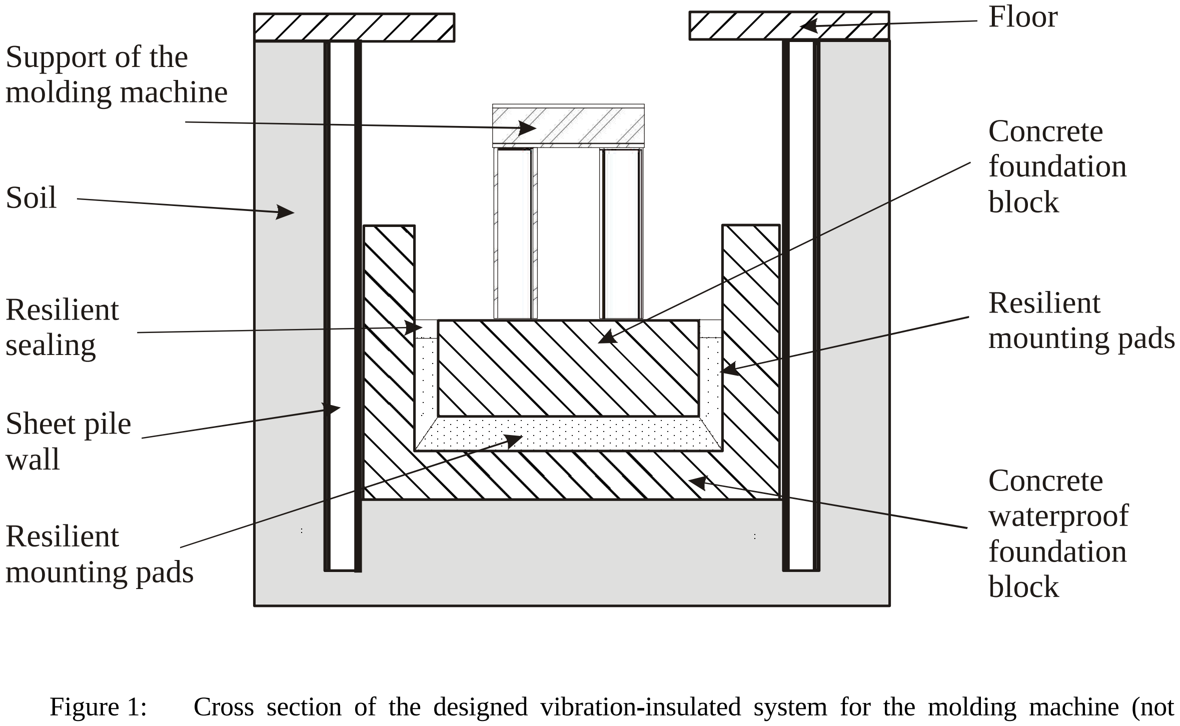

Figure 1: Cross section of the designed vibration-insulated system for the molding machine (not to scale)

The additional costs of this vibration-insulated system are approximately € 350.000,-.

4. Calculations

In order to determine the force-spectrum of the molding-process, the transfer functions Finite Element Method (FEM) calculations were made and measurement results are used. The principle of Finite Element Method is that a complex mechanical of dynamical system can be described with a finite number of elements. The properties of these elements are known and can be described numerically. Using these elements and the description of the system, the differential equations of motion of the total system can be put together [2, 3]:

$$[M]\cdot\{a\} + [C]\cdot\{v\} + [K]\cdot\{u\} = \{F(t)\}$$

where : $[M]$ = mass matrix;
$[C]$ = damping matrix;
$[K]$ = stiffness matrix ;
$\{F(t)\}$ = time dependent force vector;
$\{a\}$ = vector with accelerations in the nodes;
$\{v\}$ = vector with velocities in the nodes;
$\{u\}$ = vector with displacements in the nodes.

Based on this set of differential equations of motion, the mechanical and dynamical behavior of the system can be determined. In this study harmonic response analysis were made.

In figure 2 one of the used FEM-models is given. In figure 2 are also graphically some results of the calculations are given.

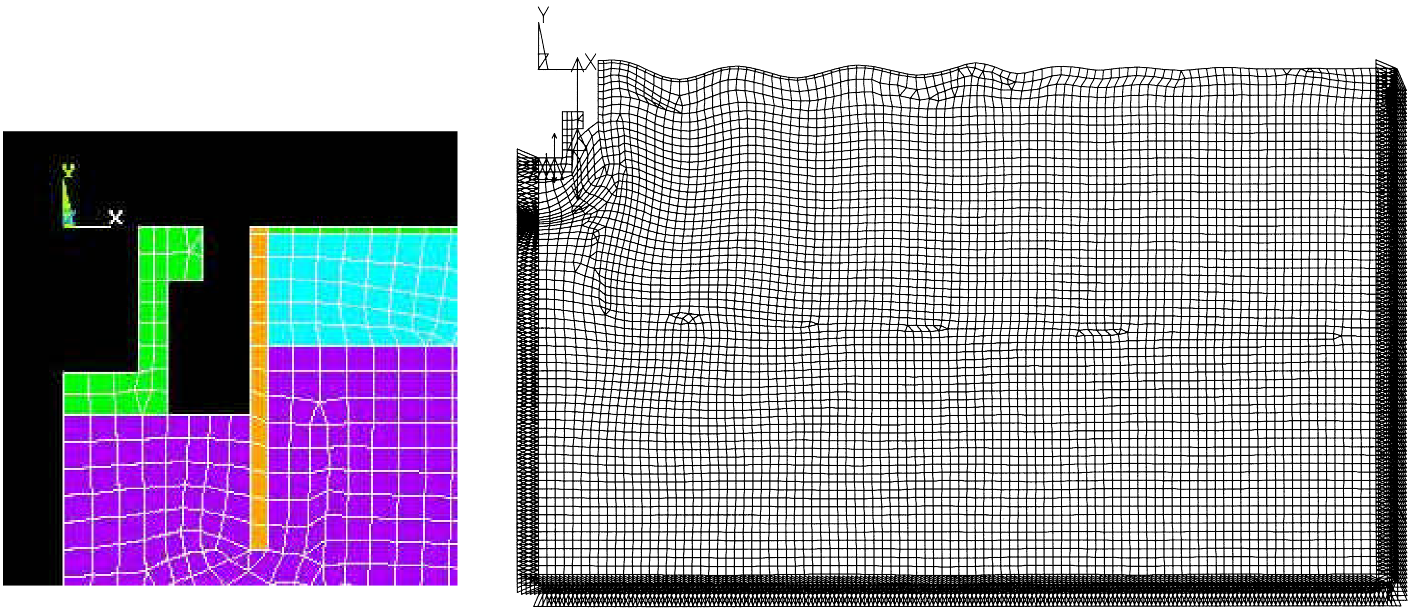

Figure 2: Symmetric Finite Element mesh of the vibration-insulated system. Also the artificial boundary elements, in order to describe an infinite soil-structure, are shown [1]. The shown (highly scaled) displacements represent the amplitude of the response of the model, excitated by a harmonic force of 16 Hz.

During the building of the symmetrically FEM-model, two different kinds of elements have been used. One type of element (plane-strain) describes the two layered soil, the concrete foundation blocks and the resilient mounting pads. The other type of element (spring-damper element) describes the artificial boundary conditions in order to model an infinite soil-structure.

In figure 2 the response of the FEM-model is given, caused by a harmonic force of 16 Hz. Using these (and other) results in the frequency domain, the transfer function from the molding machine to the vicinity can be calculated. Based on the design of the vibration-insulated system the natural frequency of oscillation of the concrete foundation block is calculated to be 9,8 Hz. The vibration levels in the vicinity of the foundry company due to the molding machine can be calculated to be less than 0,1 mm/s (over the total relevant frequency domain), using the vibration-insulated system (see chapter 3).

5 Measurements

After the decision of the foundry to choose for the impact molding machine, the complex vibration-insulated system was realized. Vibration measurements [5] confirm the calculated natural frequency of oscillation of the concrete foundation block of approximately 10 Hz. Furthermore, after realization of the (total) impact molding machinery, measurements show that the vibration levels in the dwelling-houses remain below 0,1 mm/s.

Conclusions

Calculations and measurements show that, using a complex vibration-insulated system (see figure 1), the vibration levels in the vicinity of the foundry company can be reduced to less than 0,1 mm/s. One can conclude that, when comparing different molding machines, one has to look at the total concept of the machines. Therefore one has to take into account the vibration aspects, the (production) quality aspects and the possible measures to reduce the vibrations to the environment. Doing so, one can get a very cost-efficient solution. In this case the foundry company can produce better products, for a new part of the market, in a situation that at first, from a vibrational/environmental point of view, seemed not very promising, at lower costs.

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